

ANNEX D
PHYSICAL AND CHEMICAL PROPERTIES

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Chemical Name	Distilled Mustard (HD) Diethyl, 2,2-dichloride sulfide [bis (2-Chloroethyl) sulfide]
Source(s)	FM 3-11.9
Short Name	Distilled Mustard (HD)
Chemical Formula	C ₄ H ₈ Cl ₂ S
Molecular Weight	159.07
Physical State	Pale yellow to dark brown oily liquid
Liquid Density	1.27 g/mL at 25°C
Solid Density	1.372 g/cm ³ at 0°C 1.333 g/cm ³ at 10°C
Normal Freezing Point or Melting Point	14.45°C
Boiling Point	218°C extrapolated (decomposes at 180°C)
Vapor Density (relative to air)	5.5
Vapor Pressure	0.106 mm Hg at 25°C
Volatility	906 mg/m ³ at 25°C
Viscosity	3.95 cP at 25°C
Solubility	0.092 g/100 g H ₂ O at 22°C. Freely soluble in fats and oils, gasoline, kerosene, most organic solvents, and CW agents.
Latent Heat of Vaporization	15 kcal/mol at 25°C
Special Properties	Permeates ordinary rubber
Flash Point	105°C
Corrosivity	0.0001 inch/month at 65°C on steel
Decontaminants (equipment)	HTH or household bleach
Stabilizers Commonly Used	None listed

Notes:

cP = centipoise
 CW = chemical warfare
 g = gram
 g/cm³ = gram per cubic centimeter
 g/mL = gram per milliliter
 HTH = high test calcium hypochlorite
 kcal/mol = kilocalorie per mole
 mg/m³ = milligram per cubic meter
 mm Hg = millimeters of mercury

Chemical Name	Thickened Mustard (HT) Bis-(2-chloroethyl) sulfide; T: Bis {2(2-chloroethylthio)ethyl} ether
Source(s)	FM 3-11.9
Short Name	Distilled mustard and T mixture (HT)
Chemical Formula	(H): $C_4H_8Cl_2S$; (T): $C_8H_{16}Cl_2OS_2$
Molecular Weight	188.96
Physical State	Pale yellow to brown liquid
Liquid Density	1.263 g/mL at 20°C
Solid Density	None listed
Normal Freezing Point or Melting Point	1.3 C (MP)
Boiling Point	227°C
Vapor Density (relative to air)	6.5
Vapor Pressure	7.7×10^{-2} mm Hg at 25°C
Volatility	7.83×10^2 mg/m ³ at 25°C
Viscosity	Data not available
Solubility	Slightly soluble in water; soluble in most organic solvents
Latent Heat of Vaporization	Data not available
Special Properties	Permeates ordinary rubber
Flash Point	Flash point range 109° to 115°C
Corrosivity	0.00007 inch/month at 65°C on steel
Decontaminants (equipment)	HTH or household bleach is effective on equipment. Water, soaps, detergents, steam, and absorbents (earth, sawdust, ashes, and rags) are effective for physical removal. STB does not effectively decontaminate mustard if it has solidified at low temperatures.
Stabilizers Commonly Used	None listed

Notes:

g/mL = gram per milliliter
 HTH = high test calcium hypochlorite
 mg/m³ = milligram per cubic meter
 mm Hg = millimeters of mercury
 MP = melting point
 STB = supertropical bleach

Chemical Name	Isopropyl methylphosphonofluoridate (GB)
Source(s)	FM 3-11.9
Short Name	Sarin (GB)
Chemical Formula	C ₄ H ₁₀ FO ₂ P
Molecular Weight	140.09
Physical State	Colorless liquid
Liquid Density	Munitions grade: 1.0964 g/mL at 25°C; 1.1255 g/mL at 0°C
Solid Density	None listed
Normal Freezing Point or Melting Point	-56°C (FP)
Boiling Point	150°C
Vapor Density (relative to air)	4.8
Vapor Pressure	2.48×10^0 mm Hg at 25°C; 4.10×10^{-1} mm Hg at 0°C
Volatility	1.87×10^4 mg/m ³ at 25°C; 3.37×10^3 mg/m ³ at 0°C
Viscosity	1.397 cP at 25.0°C, 2.583 cP at 0°C
Solubility	Completely miscible with water and common organic solvents
Latent Heat of Vaporization	11.6 kcal/mol at 25°C; 11.7 kcal/mol at 0°C
Special Properties	None listed
Flash Point	Nonflammable
Corrosivity	At 71°C, slightly corrosive on steel, copper, brass, inconel, K-monel, and lead as well as slight to severe amounts of corrosion on aluminum, depending on the type.
Decontaminants (equipment)	HTH or household bleach
Stabilizers Commonly Used	None listed

Notes:

cP = centipoise
 g/mL = gram per milliliter
 HTH = high test calcium hypochlorite
 kcal/mol = kilocalorie per mole
 mg/m³ = milligram per cubic meter
 mm Hg = millimeters of mercury

Chemical Name	(GD) Pinacolyl methyl phosphonofluoridate
Source(s)	FM 3-11.9
Short Name	Soman (GD)
Chemical Formula	C ₇ H ₁₆ FO ₂ P
Molecular Weight	182.17
Physical State	Colorless liquid when pure
Liquid Density	1.0222 g/mL at 25°C; 1.0456 g/mL at 0°C
Solid Density	None listed
Normal Freezing Point or Melting Point	-42°C (MP)
Boiling Point	198°C (extrapolated) decomposes
Vapor Density (relative to air)	6.3
Vapor Pressure	4.01×10^{-1} mm Hg at 25°C; 4.96×10^{-2} mm Hg at 0°C
Volatility	3.93×10^3 mg/m ³ at 25°C; 5.31×10^2 mg/m ³ at 0°C
Viscosity	3.167 cP at 25.0°C, 6.789 cP at 0°C
Solubility	Solubility of GD in water is 2.1 g GD/100 g at 20°C; 3.4 g GD/100 g solution at 0°C; very soluble in organic solvents
Latent Heat of Vaporization	13.2 kcal/mol at 25°C; 13.8 kcal/mol at 0°C
Special Properties	None listed
Flash Point	121°C (open cup)
Corrosivity	0.00001 inch/month at 65°C on steel
Decontaminants (equipment)	Use the M295 IEDK for individual equipment. STB is effective on equipment. Water, steam, and absorbents (earth, sawdust, ashes, and rags) are effective for physical removal.
Stabilizers Commonly Used	None listed

Notes:

cP	=	centipoise
g	=	gram
g/mL	=	gram per milliliter
HTH	=	high test calcium hypochlorite
IEDK	=	individual equipment decontamination kit
kcal/mol	=	kilocalorie per mole
mg/m ³	=	milligram per cubic meter
mm Hg	=	millimeters of mercury
MP	=	melting point
STB	=	supertropical bleach

Chemical Name	O-Ethyl S-(2-diisopropylaminoethyl)methyl phosphonothioate (VX)
Source(s)	FM 3-11.9
Short Name	O-ethyl methyl phosphonothiolate (VX)
Chemical Formula	C ₁₁ H ₂₆ NO ₂ PS
Molecular Weight	267.37
Physical State	Colorless liquid when pure
Liquid Density	1.0083 g/mL at 25°C; 1.0209 g/mL at 0°C
Solid Density	None listed
Normal Freezing Point or Melting Point	Below -51°C and -39 to -60°C (FP)
Boiling Point	292°C
Vapor Density (relative to air)	9.2
Vapor Pressure	8.78×10^{-4} mm Hg at 25°C; 4.22×10^{-5} mm Hg at 0°C
Volatility	1.26×10^1 mg/m ³ at 25°C; 6.62×10^{-1} mg/m ³ at 0°C
Viscosity	10.041 cP at 25°C, 37.532 cP at 0°C (extrapolated)
Solubility	Water solubility of VX is 5% at 21.5°C; miscible with water below 9.4°C; soluble in common organic solvents
Latent Heat of Vaporization	19.2 kcal/mol at 25°C; 20.1 kcal/mol 0°C
Special Properties	None listed
Flash Point	127°C
Corrosivity	Negligible on brass, steel, and aluminum; slight corrosion with copper
Decontaminants (equipment)	Use the M295 IEDK for individual equipment. STB, HTH, or household bleach are effective on equipment. Water, soaps, detergents, steam, and absorbents (earth, sawdust, ashes, and rags) are effective for physical removal.
Stabilizers Commonly Used	None listed

Notes:

cP = centipoise
 FP = freezing point
 g/mL = gram per milliliter
 HTH = high test calcium hypochlorite
 IEDK = individual equipment decontamination kit
 kcal/mol = kilocalorie per mole
 mg/m³ = milligram per cubic meter
 mm Hg = millimeters of mercury
 STB = supertropical bleach

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